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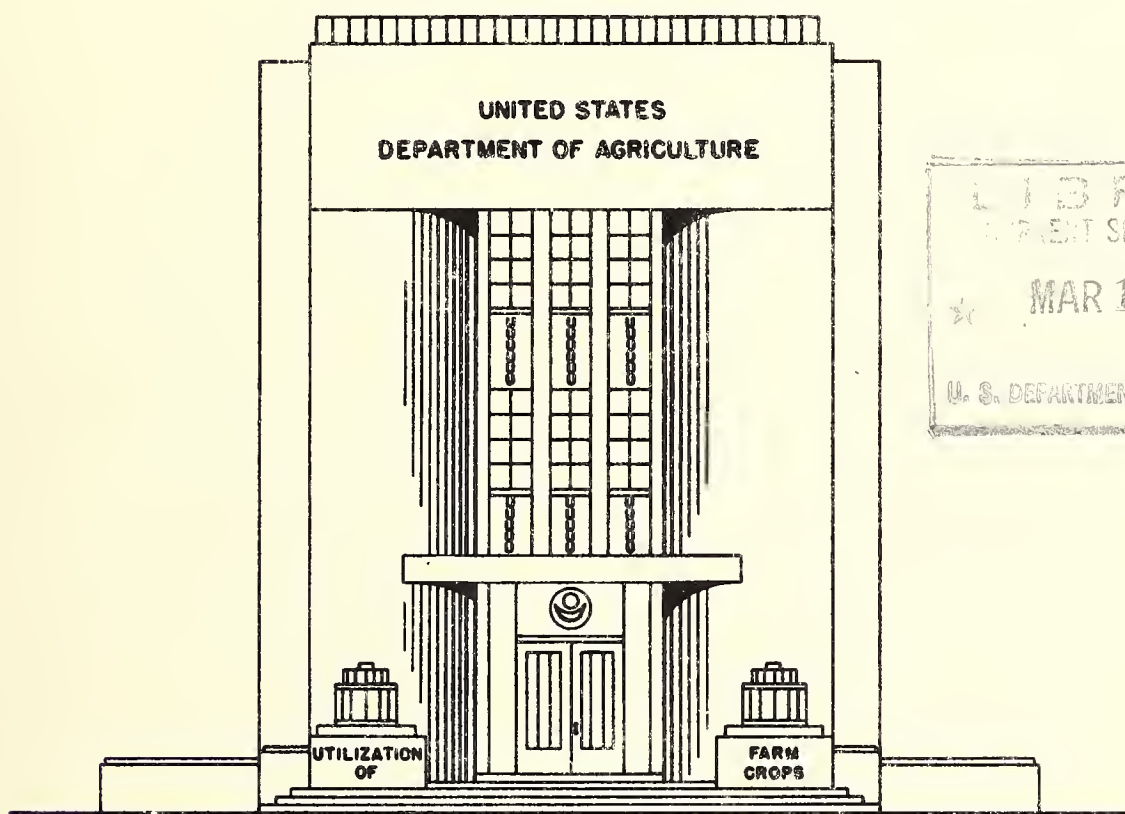
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ECONOMIC FACTORS TO BE CONSIDERED IN THE USE OF SUGARCANE BAGASSE
AS A RAW MATERIAL FOR PAPER AND BOARD MANUFACTURE



By

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NOVEMBER 1954

EXCEPT FOR COVER,
PAPER USED IN THIS BULLETIN CONTAINS
49 PERCENT BLEACHED WHEAT STRAW PULP
AND 51 PERCENT BLEACHED WOOD SULFITE
PULP.

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ECONOMIC FACTORS TO BE CONSIDERED IN THE USE OF
SUGARCANE BAGASSE AS A RAW MATERIAL FOR PAPER
AND BOARD MANUFACTURE¹

By

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INTRODUCTION

The delay in utilizing sugarcane bagasse as a raw material for manufacture of cellulose pulps is due, in a large extent, to the belief by both the sugar and cellulose industries that it was either a waste or a low-grade byproduct. This thinking led to an underestimation of the importance of economic and technological factors. Not until about 30 years ago did any industry based on the utilization of bagasse make a lasting success. This was the manufacture of thermal and sound insulating products from bagasse in Louisiana. Fifteen years ago the first successful manufacture of paper from bagasse was started.

The sugar industry in general uses bagasse as a fuel. Over the years, improvements have been made in sugar-house operation, particularly in heat economy, so that in manufacture of raw sugars, in well-operated houses, a surplus of bagasse up to 30 percent or more exists. Generally this excess is burned merely to dispose of it. With the manufacture of refined sugar and/or alcohol as processes associated with the sugar mill, there is little or no surplus. The fiber content of cane varieties also governs the extent of excess over fuel requirements. In any event, a sugar company has generally been interested either in a market for excess bagasse, or for all of it, so as to replace it with gas or oil and obtain a small bonus besides. It has been demonstrated that gas or oil are better fuels and make for improved sugar-house operations. But sugar companies, with few exceptions, have had no interest in upgrading the bagasse, nor in problems of handling, storing, and converting it into other products.

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² The Northern Regional Research Laboratory was designated as the Northern Utilization Research Branch of the Agricultural Research Service, under the recent reorganization of the Department of Agriculture.

On the other hand, industries purchasing bagasse have had little knowledge of problems of the sugar industry and were only interested in obtaining a stable source of raw material at as low a price as possible.

Experience in successful utilization of bagasse, except for fuel, has shown that this loose buyer-seller interest must be strengthened by closer association. The Louisiana company first successfully using bagasse became financially interested in sugar manufacture so as to insure supply, improve quality, and lower handling and storage costs of its bagasse. When manufacture of insulating products was undertaken, first in Australia and later in Hawaii, sugar interests initiated, financed, and managed the developments. Likewise, the first successful manufacturer of paper from bagasse operated a sugar company.

Now interest in using bagasse to make paper and board has become very real again. From the many inquiries directed to the Northern Utilization Research Branch, it is evident that neither paper nor sugar manufacturers have a clear understanding of each other's problem and do not appreciate the full significance of economic and technological factors under their joint control that may contribute to lasting success in both industries. Much new information is available, particularly new technical information. It seems desirable, therefore, to discuss the subject fully so that new ventures into bagasse utilization may be made with the least risk of failure.

FACTORS RELATING TO BAGASSE PRODUCTION

Bagasse is the fibrous residue left after sugarcane is crushed and the sugars and soluble materials are extracted. It is not a uniform material. It varies in both physical and chemical properties from locality to locality, from mill to mill, and from season to season. Fresh bagasse is different from stored bagasse not only in physical and chemical but also in pulping characteristics. This is the first important point to grasp.

Variations Due to Cane Culture.

Like all agricultural crops, yield and quality of cane are dependent on cane variety as modified by local soil conditions, practices of cultivation, fertilizer application, rainfall, and climatic changes. In many countries the sugarcane plant is harvested before it reaches maturity, the growing season being 9-10 months, except in Hawaii where the growing season is about 22 months. The lignin content of plants increases as they approach maturity. In Table 1, it will be noted that lignin content of Hawaiian cane varieties is generally higher than those from other localities. Hawaiian bagasse is more

difficult to pulp, largely on this account. Sugarcane is subject to many diseases and to insect attack, and constant study is under-way to develop better and more resistant varieties of cane.

The sugar planter desires a cane giving the highest yield of sugar per acre. Very high yields of cane and of sugar have been recorded. Three records, in long tons, are: 129.1 tons of cane per acre from P.O.J. 2878 in Mexico; 126.6 tons of cane, with 14.3 tons of sugar from H. 109 in Hawaii; 122.4 tons of cane, with 11.545 tons of sugar from Co. 410 in India. Many verified yields of 90 to 110 tons of cane per acre have been reported from numerous countries. The percent fiber, including pith, in cane varies from less than 10 percent in some varieties to as much as 17 percent in others. Large-barreled canes contain more pith and generally less fiber than small-barreled canes. Small-barreled canes have an exceedingly hard rind, are generally resistant to borer attack, and mill differently than softer canes. In Table 2, variation in the relationship between pith and true fiber content of 3 Florida varieties of cane is given.

The yield of cane can vary considerably from year to year. When varieties become subject to disease, the situation may become disastrous. For example, in the late 1920's culture of cane in Louisiana was almost wiped out. The introduction of new P.O.J. varieties, developed by Brandes of U.S. Department of Agriculture, and of improved fertilizer and cultural practices, restored the industry. To the variable factors mentioned, there must be finally added that of sugar quotas.

All of these factors are related to the quantity of potential bagasse. Since it is clear from this discussion that numerous conditions, not always under control of the sugar planter, may cause total or surplus bagasse to fluctuate annually in any locality, careful surveys must be made before locating paper mills to use bagasse. Past history of bagasse availability should be reviewed and production of the contemplated mill should be somewhat less than evident bagasse availability. In addition, plans should be made to provide ample stored bagasse to meet such contingencies as a partial crop failure, or loss of a portion of stored bagasse through fires.

Variations Due to Cane-Harvesting Practices.

Harvesting practices also have some effect on the quantity of bagasse produced, but most importantly they affect quality.

To have efficient sugar-house operation the cane should be topped and the leaves removed before it is ground. The growing top of the cane plant contains a high proportion of glucose. If this part of the cane is also ground, yield of crystallizable sucrose is reduced and that of molasses increased. Leaves are generally referred to as trash, and, depending on harvesting practices, tops are sometimes included in trash. Table 3 gives an idea of the amount of tops and trash associated with cane ready for grinding. Dymond (1) also states that tops from 5

million tons of cane would contain 34,800 tons of sugars, which at 90-percent extraction would produce 3.76 million gallons of alcohol. He says that, as silage, tops from a 40-ton crop on one acre would provide the feed requirements of 200 mature animals. Table 4, also from Dymond, gives an estimate of important fertilizer constituents of these two materials.

Methods of disposing of leaves and tops varies in countries and on plantations, depending partly on the availability of cheap labor. In any case these practices influence the quality of bagasse. In many localities, it is the practice to burn leaves from the standing cane in the field. This method has long been under debate, because of possible effects on purity of cane juices and of the reported lessened vigor of the following ratoon crop of cane. Where hand labor is available at low cost, leaves and tops are removed by hand in the field and the trash is generally added back to the soil. Shortage and high cost of hand labor mean that cane growers must rely more and more on mechanical harvesters. Machine-cut cane carries much more trash than hand-cut cane, even when the trash is burned. This means that inert fibrous material must be passed through the mills along with considerable dirt or stones. The result is more sugar lost in the bagasse and a lower purity of juice; a slower grinding rate, due both to the greater volume of fiber and to the extra time for clarifying the juice; more filter muds to handle; and increased wear and tear on equipment. It has been stated that in Louisiana where a factory grinds a mechanically harvested cane containing 10 percent of trash, not unusual in that location, total losses that can be charged to trash may amount to \$1.00 per ton of cane ground (2). Due to the structure of cane leaves, they have very little value for making any but the lowest grades of paper.

From the standpoint of economical sugar manufacture, high content of trash in mechanically harvested and loaded cane is bad enough, but equally bad is the large proportion of soil, which creates great difficulties in the mills, fouls the juices, and imposes extra loads on clarifiers and filters. In Hawaii, this dirt problem has become even more serious. A method of harvesting has been developed which consists in breaking off cane near the ground by means of bulldozers and loading the cane, without removal of leaves or tops, into trucks for transport to the sugar mill. This has caused development of extensive cleaning plants to remove the excessive rock, dirt and trash before grinding. In Hawaii, the topping of cane is not so important because of its greater maturity. Evidently interest of the sugar-mill operator is in receiving or preparing cane as free from trash and dirt as possible before grinding.

Little need be said about the undesirability of dirt in bagasse for paper or board manufacture. A small amount might be tolerated in low-quality board, but in bleached and fine papers its presence in

bagasse will be a continual source of trouble and expense. Trash lowers the quality of bagasse as leaf fiber is suitable only for low-grade board products. However, Singh (3) in describing a new agricultural-industrial development revolving about sugarcane at Walchandnagar, Bombay province, India, says that "the trash, which represents 12-15 percent of the total weight of the cane, is manufactured into paper and cardboard in the estates' own pulping mill."

When leaves are burned from cane, the ends of many leaves where they join the stalk remain as carbonized material. In ordinary washing and milling processes, these carbonized fibers remain in the bagasse. An examination of samples of bagasse from Hawaii, Florida, and Puerto Rico showed many such carbonized areas. Buds at nodes of the cane are carbonized in the same manner and carry through into the bagasse. Presence of carbon in the bagasse, particularly when bleached pulps are to be made from it, is much more serious than the presence of dirt. Generally the dirt, where it is freely suspended, may be removed by sufficient separation treatments but the carbon, having a density close to that of the fiber and being friable, is almost impossible to remove from the pulp.

Variations Due to Milling Practices.

A description of characteristics of the fibrous elements of the cane stalk as it enters the mill is of interest. The outside of the stalk comprises a relatively tough rind. The inside consists of soft medullary tissue in the cells where the sugar is deposited. Lengthwise through this tissue run numerous fibrovascular bundles of various sizes so placed that the smallest are packed near the outside and the larger ones, less abundant, are distributed towards the center. The rind is formed of thick-walled, elongated cells of sclerenchymatous fibers. The fibrovascular bundles comprise groups of fibers and ducts. The pith, parenchymatous cells, is short, broad, and of low resistance. These cells group around and adhere both to the fibrovascular bundles and rind fibers. The outside of the rind often appears glassy, carries a coating of wax, and may be of a number of colors.

At intervals in the length of the stalk, which vary in accordance with conditions of growth of the cane, the fibrovascular bundles send branches outwards thereby forming a portion of dense tissue called the node. Neither the pith nor the tissue concentrated in the node is suitable for papermaking (4).

Extraction of juice is only possible when the cells and tissue of the cane are ruptured. This rupturing action can be advanced by shredding or using knives, but must be completed under compression exercised between grinding rolls. Purpose of the extracting rolls is to pass the fiber and to hold back the juice contained therein. This extraction can only be achieved in high degree when the compressed

bagasse between the coacting rollers forms a juice-tight seal, so that the extracted juice cannot be reabsorbed by the bagasse which has passed the maximum pressure between the rolls. The completeness of extraction depends on fineness of the bagasse and quantity of juice it contains. Since bagasse will always hold a certain amount of juice or liquor by capillarity, 100-percent extraction is impossible to attain.

The first set of rolls after the knives, or shredder, are crushers. Even if the cane has been previously shredded, its degree of fineness produced by the crusher is not very great, but the quantity of juice is 5 or 6 times that of the fiber and normally a 40- to 60-percent extraction is obtained at the crushing rolls. This relieves the work of the first set of rolls of the cane mill. All rolls, including the crusher rolls, are maintained under hydraulic pressure. Fresh water, called maceration water, is added to the bagasse to obtain maximum extraction. Shredders, knives, crushers, and cane mills differ greatly in design, width, and length. Such milling equipment may vary from a crusher with a cane mill of 9 rolls, to a complete chain of knives, or shredders, crusher, and a cane mill of 18 rolls. The subject of juice extraction is intricate and much attention has been devoted to engineering problems involved.

The physical character of cane, whether hard or soft, has a pronounced effect on the character of bagasse. It is evident that bagasse ground and extracted with the most complete milling equipment will be composed of shorter fiber bundles than the same material milled on smaller, lighter equipment. Heavy-milling equipment will loosen more pith from the fiber than light-milling machinery. The shredding operation will greatly assist in loosening pith and carbon particles as well as increasing extraction. Since bagasse acts as a filter mat for the juice in the extraction process at each set of rolls, the dirt and carbon will be worked into the bagasse more thoroughly on a big mill than on a small one. Dirt on the cane consists of fine silt or powdered soil and is spread over the surface of the pith and fiber more or less uniformly during grinding. The surface area of pith as compared to that of the fiber is greater in any sample of bagasse, so pith will pick up and hold a proportionately larger amount of dirt and carbon particles. In some mills, muds from filters are spread on the bagasse as it is conveyed from the cane mill. This practice must be stopped if bagasse is to be pulped. Generally some of the bagasse from the cane mill is passed over rotating or vibrating screens to separate loose pith and fine fibers which are used to assist in the more rapid settling and filtration of the juice. This practice is desirable.

The average amount of maceration water added is said to be 100 parts to 140 parts of bagasse. Moisture content of bagasse from the cane mill may vary from a low of 41 to approximately 50 percent, and often runs about 48 percent. Sucrose remaining in the bagasse varies, depending on conditions, from 2 to 5 percent. Keller (5) states that

the color of bagasse will vary from a greyish-white to a very dark green. The material is nonhomogeneous in size, varying from a dust that will pass a 60-mesh screen to particles around 6 inches long by 3/8 inch in cross section. Usually about 97 percent will pass a 1-inch square opening. The analysis on an "as produced" basis is about as follows:

	<u>Percent</u>
Moisture	49
Fiber and dirt	45
Soluble solids	6

Bagasse is only one of the products produced in the sugar house in processing cane. Table 5 gives data calculated by Martin from reports by Grayson (6) of the U. S. Department of Agriculture on the average composition of materials obtained in processing a ton of sugarcane in the 1948 crop.

It will be noted that bagasse comprises about one-third the weight of the cane, and slightly more than the raw sugar produced. Keller says that probably 95 percent of bagasse produced annually is burned. There has been little incentive for most sugar mills to do more about improving quantity or quality of bagasse than absolutely necessary for their sugar operations.

This discussion shows that many factors may affect the quantity and quality of bagasse available at a sugar mill. Like most crops, in the culture of cane attention has been directed almost entirely to the fruit produced, sucrose, and practically none to anything excepting the nuisance value of the byproducts.

BAGASSE AS A RAW MATERIAL

Fuel Value.

Only a portion of bagasse produced is waste material, in the sense that its disposal involves expense. Bagasse is a high bulk material, having a weight, as produced, of about 10 lb./cu. ft., and is ordinarily conveyed directly to the boilers or to the loose-storage pile, which serves as a standby for fuel when the cane mill is not operating. Bagasse is a good low-grade fuel. With present boiler design, there is generally more bagasse produced than is needed for all of the sugar-house fuel requirements. If no other use is made of the surplus bagasse, it is used in the furnaces, resulting in lower efficiency, and greater expense, or it is stored in piles which are later burned. Gastrock and Lynch (7) give a chart for calculating the fuel value of bagasse in terms of oil, gas, or coal. The

calculations take into account relative calorific values, boiler efficiencies and unit fuel costs. One ton (2,000 pounds) of bagasse, 50-percent moisture content, has a fuel value of 6 million B.t.u. equivalent to 6,000 cu. ft. of 1,000-B.t.u. gas, or 1 barrel of fuel oil (42 gallons). Dry bagasse would have twice this fuel value. In some places bagasse is baled for use as fuel after the grinding season; during storage its fuel value increases due to loss of moisture. In Java (8) briquettes were made from bagasse to supply fuel for cooking and other purposes.

Cost of fuel to replace bagasse in sugar-house operation will vary widely depending on location, and availability and cost of the fuel. Duty on oil in some countries is so high that its replacement of bagasse as fuel is out of question. Louisiana is particularly favored with low-cost gas and oil, and this may have been one reason why it was possible to start a successful industry based on bagasse as a raw material. On the other hand, gas and oil as fuels are much to be preferred in sugar-house operation, and no sugar house that has used either of these fuels will of its own choice return to use of bagasse for fuel.

In making economic surveys for the location of industries based on the use of bagasse, the question of fuel requirements deserve the most careful consideration.

Present Uses, Other Than as Fuel.

Efforts to make valuable products from bagasse have occupied many minds for more than a century. Results of all this work are meager indeed, and even now less than one million short tons of bagasse, dry basis, are used annually in the world for any purpose other than fuel at the sugar mill. Building material products are now made from bagasse in Louisiana, Hawaii, Australia, and, before the war, in Formosa and England. The technology of these operations is now well understood. Several companies are prepared to build mills for this type of manufacture, so that its establishment in still other countries depends only on solving sales and economic problems. In Louisiana and Florida, bagasse is processed into chicken litter, and into mulch to replace sphagnum moss, a business that is not only proving profitable but also shows increasing sales volume year by year. For this purpose the bagasse is dried, as it is produced, using rotary driers, screened to remove as much pith, fine fiber, and dirt as possible, and baled. In some mills, the moist bagasse is also screened before drying. After drying, the material is passed through a coarse hammer mill to loosen more pith before final screening. It is possible to operate such a plant after the grinding season by using baled, stored bagasse. The material prepared from fresh bagasse is brighter in color, less friable, and cleaner than that made from stored bagasse. The cost of preparing mulch and litter from fresh bagasse is lower, in spite of the cost of drying.

In making mulch and litter, a byproduct of mixed pith and fine fiber is obtained. By screening this mixture, pith of low density and relatively high absorption capacity is obtained for use in manufacture of dynamite. Mixtures of pith and fine fibers are used to absorb molasses intended for feeding purposes. Cattle raising is increasing rapidly in the southern United States, and more molasses is being fed. Some sugar mills find manufacture of mulch, litter, and feed materials so profitable that they do not seem to be greatly interested in using bagasse for paper manufacture.

Efforts to manufacture paper from bagasse began a century ago, but of the many companies started, none operated for any length of time. In general, failures can be attributed to a lack of appreciation of technological and economic factors involved. In some cases, the plants were too small for economical operation; in others, handling costs and imperfect methods of storing bagasse were at fault. Generally the goal was to manufacture papers for which the material was not suited, using methods intended for pulping wood. In the late 1930's, interest revived in the possibility of making paper from bagasse. By this time the problem of storing bagasse was solved, and methods for economical baling and handling had been developed. A better understanding of the technology of pulp manufacture had been gained in many laboratories.

At the present time, 10 paper mills are known to be operating to make pulp from bagasse. Most of these mills blend bagasse pulp with wood or bamboo pulps to make a variety of papers or boards. Three mills, in the Argentine, the Philippines, and India, use the Celdecor process to make bleached pulp, and another mill is beginning operations in Brazil. Two mills in Peru use a modified kraft process to make board, and a wide variety of papers, including newsprint for the Peru market. A mill in Formosa is making unbleached and bleached bagasse pulp by the neutral sulfite process. Two small mills in the Argentine are making board from soda-process pulp, and another in Columbia from lime-process pulp. Finally, a new mill has started in Mexico producing pulps and paper by the mechano-chemical process.

In all these mills, with possible exception of the board mills in Columbia and in Argentina, as much pith as possible is removed from the bagasse before pulping. Methods for removing pith will be discussed later.

Storage and Handling.

In most countries cane-sugar manufacture is seasonal. In Louisiana, the season lasts 75 to 90 days, in Florida and the West Indies 120 to 150 days, and in some countries such as Hawaii or Peru, about 11 months. Since a paper or board mill should operate the year round, provision must be made to store fiber for somewhat more than a year to meet all contingencies.

As noted, bagasse contains about 50 percent moisture and from 2 to 5 percent sugar. Soil from cane fields inoculates the bagasse with all types of microorganisms. Unless strong chemicals that prevent growth of the organisms are intimately mixed with the bagasse at once, or unless the bagasse is immediately dried to about 15 percent moisture content, it is impossible to prevent fermentation processes from being initiated. Storage of this fiber without serious loss in quality and quantity posed an extremely difficult problem.

It fell to the lot of the writer, as director of research of the Louisiana company starting manufacture of insulating-board products, to find the successful solution of this problem. While the methods developed have been described by Lathrop and Munroe (9) and are detailed in their U. S. patent 1,920,129, recent published discussions of storage methods have not clearly brought out the necessary principles which apply, or some precautions which should be observed.

During the first grinding season in 1921 in which the company operated, part of the bagasse was blown into loose piles and part was baled. The material in the loose piles underwent severe rotting in a period of 2 to 3 months. It was later established that a wood-destroying toadstool was largely responsible for this. The baled material was stored in uncovered piles and an examination of many bales stored for the full season showed considerable evidence of rot and some of the bales were blackened on the outside as though they had been carbonized. Previous attempts to store baled bagasse in Louisiana had resulted in fires due to spontaneous combustion. The writer estimated at that time that loss of bagasse during a season's storage was about 30 percent, a figure which was later substantiated.

A research program lasting about 5 years was required to solve the storage problem. Unfortunately, it was found that results obtained by experimenting with small piles were quite misleading. During the final year of the investigation the research department supervised storage of the entire production of one large sugar mill on an experimental basis. Every bale was weighed in and out of the piles. Exact labor costs were kept, and in some cases whole piles of 500 tons or more of fiber were run through the board mill to determine the effect of a particular storage procedure on quality of manufactured product.

Due to the presence of sugar, moisture, and yeasts in the bagasse, sugar is fermented to alcohol in the course of a few hours, and in turn, in the presence of bacteria and oxygen, the alcohol is fermented to acetic acid. Both fermentations produce a great deal of heat, and large volumes of carbon dioxide are also produced by the alcoholic and other fermentations which follow the two mentioned. It was observed that if the moist bagasse was baled promptly and placed in large piles, the temperature inside the piles rose to 60° C. in the course of a week or so. At the same time, the gas given off at this high temperature by the fermentations reduced the moisture content

of the bales rapidly. At this temperature growth of many bacteria, fungi, and other organisms that would destroy the fiber at lower temperatures was stopped. It was found that the interior mass of bagasse took about 3 months to cool to normal air temperature. It was obvious that if bales were piled so as to provide air channels in the pile, the moisture could escape more freely and the material would dry out faster.

When the bagasse is dried to about 20 percent moisture content, danger of rotting is practically eliminated. There were two other reasons for piling in this fashion: One was to avoid local heating that would bring about spontaneous combustion, and the other was to prevent action of the hot acetic acid from making the fiber unsuitable for pulping. If the bales were piled too close or if ventilation channels were clogged, due to loose bagasse, it was noted that some fiber would have a coffee-brown color, and an acid odor and taste, and would be brash and brittle and very difficult to pulp.

In locations where piles of stored bales would be subject to only a little rain, the method described would be sufficient, but in Louisiana there are many rains. Two other provisions had to be made to cope with rains. One was to place a roof over the piles. The most practical one was made from galvanized iron panels which roofed the piles like shingles. The panels were dipped in asphalt to withstand corrosive action of the acetic acid in vapors rising from the piles. These panels, kept properly coated with asphalt have lasted for 20 years or more. It was found that a tarpaulin, or other protective covering placed over the top of the pile and held down over the sides was not suitable since the water ran down the tarpaulin and into the pile. Furthermore, these coverings lasted only for a year or so.

It was necessary also to protect outside bales from rotting due to wetting by rains. For this purpose, it was found that a small amount of boric acid placed in a continuous layer on the outside top edge of each bale on which the under edge of the next bale rested, as the pile was made, supplied sufficient fungicide to effectively stop the growth of destructive microorganisms. Boric acid was also spread over the top bales because of the drip of condensed moisture that took place at night from the under side of the metal roof. Piles were erected only on cleaned, slightly raised, well-drained soil. Cinders should not be used as a base. All precautions noted are necessary, and if properly used the loss of fiber on the dry basis during storage of 18 months should not exceed 10 percent. Furthermore, the fiber will be uniformly free from badly rotted areas. Borax, instead of boric acid can be used, and at present a product, Borascu³, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 3\text{H}_2\text{O}$, is available. More recently, use of boron compounds to preserve straw in storage has been adopted by the American strawboard industry.

³ Mention in this article of commercial products or their manufacturers does not constitute an endorsement by the U. S. Department of Agriculture.

Wet bagasse is hard to bale and balers built for cereal straws and such dry residues are not sufficiently strong and rugged. Several suitable makes of balers are available in the United States. The latest model is provided with mechanisms for automatic wire tying. A single baler of this type has a capacity of about 200 tons of bagasse in 24 hours. In the United States, Peru, and Mexico, the standard-size bale is 17" x 21" x 30" long and weighs wet, about 250 lb.; dry 125 to 135 lb. It is noted that plants using the Celdecor process in the Philippine Islands and India make bales 12" x 12" x 24" long containing 90 lb. of wet bagasse. Making and handling the smaller bales is more costly than that of larger bales, unless very low-cost labor eliminates the possibility of mechanical handling.

It will be found that after the bales are formed and tied they will expand in volume. In the early days of the industry, this resulted in the breaking of many wire ties, with the result that much loose bagasse had to be handled from storage piles. The solution to this problem was to obtain baling wire having a high elastic limit. After bales have been stored for some months and have dried out, the material compacts into a rather hard mass, which requires some effort to break down to loose fiber for pulping. This can be done with hand labor using pick axes, or with bales breakers. The stored material is generally extremely dusty and is preferably treated to remove the dust before pulping. The wires removed from bales should be carefully collected since pieces of wire can cause many hand and foot injuries. Laborers should be given protection against bagasse dust, since there have been cases of lung injury due to exposure to it.

Baling, storing, and handling bagasse are expensive operations. Every effort must be made to eliminate unnecessary work. Experience has shown that the operations can be highly mechanized. Bagasse piles are about 66' x 100' x 25' to 30' high. The piles should be sufficiently distant from each other to prevent fire from traveling from one pile to the other. Weeds should be kept from growing near the piles, and employees must be warned against smoking while working on or near the piles. A number of fires have occurred in bagasse piles, but so far as is known, all of these are believed to have been due to carelessness. A fire once underway in a pile of bagasse cannot easily be put out, since the material will continue to smolder for days. The best method is to completely drench the pile with water, so that the pile can be taken down in every area to which the fire has penetrated.

Generally it is necessary to build at the sugar mill a baling station to which the loose bagasse is conveyed on a belt. Installations for the necessary baling equipment, housing, yards, switch tracks, loading cranes, and living quarters, according to Keller in Louisiana, would cost about \$150 thousand for a size adequate to handle 15 thousand tons of fiber per season. The bales as produced are moved into the storage yard by tram car or truck and are lifted by a crane, using a special kind of tong or grab, in groups of 6 to the top of the pile being formed and are stacked in a definite pattern so that proper

channels for air circulation are formed. When the piles are taken down, the same tong is used to load 6 bales at a time onto cars for transportation to the board mill.

Keller (5) also gives the following costs for baling, storing, and placing bagasse on cars at the sugar-mill site:

Purchase price of bagasse	\$2.50 ton oven-dry (O.D.) fiber*
Baling, stacking, and covering bagasse in field	\$6.00 ton O.D. fiber
Loading costs and storage to railroad cars	\$.50
Total cost at sugar mill	\$9.00 ton O.D. fiber

To this cost must be added transportation to the board mill, costs of unloading and handling into the mill. The total cost including the 10-per-cent loss of fiber during storage will be close to \$12.00 per ton O.D. fiber.

ECONOMIC USE OF "TOTAL BAGASSE"

At the present time no method exists for the economic use of "total bagasse." When the sugar mill uses bagasse as fuel, some of the pith and fine fiber is screened out and finds good use as an aid in settling and filtration of juices, but not all bagasse is needed for fuel. When bagasse is baled for storage, losses in fiber occur. When the whole bagasse is used for manufacture of insulating or hardboard products, losses of pith and fine fiber to the white water, or sewer system amount to 10 to 15 percent. When bagasse is used for paper or board manufacture, most companies make an effort to separate as much pith or fines and dirt as they can by dry screening. When bagasse is upgraded by processing into litter or mulch, pith and fine fibers are separated by screening operations, and some uses have been found for these. Uses as special fillers in dynamite or as absorbents, particularly for molasses in feeds, are profitable. This type of upgrading approaches total-bagasse utilization most closely.

In essence, profitable use of "total bagasse" is the problem that needs to be solved. The writer believes that already a technical answer to this is at hand. Whether economics will permit practice of the technology will depend on a variety of conditions, not the least of which will be conservatism and inertia on the part of both the sugar and the paper manufacturers.

* Fuel value plus slight bonus, based on gas at 16.66 cents per million Btu.

Objections to Pith in Paper Manufacture.

From the standpoint of pulp and paper manufacture, those of us who have had practical experience in the industry know quite well the innumerable difficulties that may be caused by broken fibers in the form of flour, ray cells, bark particles, and unorganized tissue. Difficulties that whole bagasse with its pith, dirt, carbon, and other unorganized matter can contribute to papermaking are of like character. This is not a new observation; Dr. A. D. Little voiced it 40 years ago. In Cuba and in Hawaii, before the first World War, experiments were initiated by his organization to find practical means for removing pith. This observation concerning the disadvantages of pith has also been made repeatedly by other men highly experienced in pulp and paper technology. The real difficulties have been that there was no profitable use for the pith, once it was removed from the fiber, and no practical low-cost method had been found to prepare pith-free fiber. In addition, the whole burden of doing these things fell to the lot of the pulp or paper mill interested in using bagasse.

There is nothing mysterious in the behavior of pith in the operations of pulp and papermaking, although sometimes patent claims would make it appear otherwise. To clear up this matter, it seems desirable to trace with care just what happens to pith in bagasse during pulping, bleaching, and papermaking operations.

The amount of fiber, pith, dirt, and solubles in bagasse from Louisiana, Florida, Hawaii, Puerto Rico, and the Philippine Islands is given in Tables 2 and 6. There is a notable variation in these relationships. Table 1 gives the chemical analyses of bagasse from these same countries or regions, including samples of different varieties, and for different years. It will be noted that in all cases the pith contains more ash, is generally higher in extractives, equally high or higher in lignin content, generally higher in pentosan content, and lower in cellulose than fiber from the same sample of bagasse.

In considering these data it must be borne in mind that the pith and fiber were separated from each sample by a wet method, in which sufficient water was used to remove the dirt that would readily wash from the material.

Table 7 presents data showing chemical composition of samples obtained by fractionally screening a sample of Japanese bagasse (10). It will be noted that the ash content of samples increase as the fractions pass smaller mesh screens, the extractives likewise increase, while cellulose and alpha-cellulose content decreases. It is important to note that pith and fine fibers are covered with dirt and collect dirt.

Pulping is a chemical reaction taking place on surfaces. The greater the surface exposed to the chemical, the more rapid the pulping action.

It follows that pith and fine fibers will pulp more rapidly than coarse ones; they will consume chemical more rapidly, making pulping less uniform. Pulps must be agitated in chests, passed through pumps, over screens, and collected on wires. All these mechanical actions break up pith particles and increase their loss to the sewer. Since hydration of pulp is also related to surface area, pulps which contain pith hydrate more rapidly, have slower drainage, shrink more on drying, and produce harder papers than normal pulps.

If such pulps are bleached, presence of pith causes higher bleach consumption, since dirt which is absorbed in the pith cells can only be removed by destroying the pith; excess bleach will reduce pulp yield and produce weaker pulp. When carbon is present it may not be possible to obtain a highly bleached pulp.

The contention that if proper pulping methods are applied to whole bagasse, pith is an asset rather than a liability, is pretty much nonsense. Dirt is inside the pith cells when the whole bagasse goes into the cooker; to remove it the pith must be destroyed to the point that the dirt content of the pulp is not objectionable. Methods of pre-hydrolysis followed by washing and pulping consist essentially in using chemicals to get rid of the pith. Yields are low, chemical and operating costs high, and the pulps are weak.

It is clear that pith may perform a useful function in specialty products as suggested by Wells and Atchison (11), but in such cases the pith should be separated from the bagasse, given the necessary treatment and blended with paper pulps in amounts needed for the specialty boards or papers.

Presence of dirt in board pulps and in lower grade pulps used for cheap wrapping is not so serious. What is serious is the low drainage rate of pulps containing much pith, since these demand slow paper machine operation. High production rates make possible better pay for labor and better labor. While it may be thought that small mills can survive using small machines running at low speeds, the whole trend today is towards faster operation. The investment in paper mill is high and is warranted only if the mill can operate successfully for a long time. It is, therefore, most important to consider the competitive forces which will be faced in starting such manufacture.

At the present time bleached and unbleached bagasse pulps are being made commercially from partially depithed bagasse in a number of countries. While most boards and papers made in this way would have difficulty in competing in world markets, they can at present fulfill definite needs in countries in which they are produced. As the technological standards of these countries improve such operations will find it more and more difficult to survive.

On the other hand, pulps can be made from depithed bagasse that can compete in any market. By proper blending, improved board and paper products can be made in any country. These pulps will be obtained by applying the best pulping techniques to pith-free fiber. Evidently, to accomplish this, two developments are necessary: (1) A practical method for separating pith, and (2) a use for pith that will make both pith-free fiber and fiber-free pith highly desirable, profitable raw materials.

Methods Used to Separate Pith.⁴

All commercial methods used for mechanically separating pith depend on dry screening. Such methods will remove only about one-third of the pith from either stored baled bagasse or artificially dried material. The remaining pith is firmly embedded in rind fibers or covers fibrovascular bundles. Some of this pith is loosened if the material is passed through hammer, or like mills, but this action breaks up a good deal of fiber, and a mixture of about half pith and half small fibers is removed on screening. Less severe hammer milling loosens less pith and breaks up less fiber.

At one sugar mill, where an excess of bagasse for fuel exists, enough bagasse is mechanically treated to produce the fiber requirements of the associated paper mill. The cleaned fiber is baled and the remainder is used for fuel. In this case, quality of the pith does not matter and since the excess fiber cannot be used for fuel it is obtained at low cost. A method of this sort is not widely applicable.

It is generally recognized now that to obtain a separation into pith and fiber, both of high quality, the material must be processed in a wet state to loosen the pith. By rubbing wet bagasse vigorously between the hands it is easy to demonstrate that the pith will be loosened without damaging the fibers. It has been difficult to find a machine that will duplicate this treatment. Until recently no practical method has been found for separating loosened pith from the fiber, in order that high-grade materials could be recovered in high yield. For several years the Northern Regional Laboratory has been engaged in a determined effort to solve this problem. In 1951, it was announced that a practical method (12) for loosening pith had been found. The Hawaiian Sugar Planters' Association was also interested in this problem and has collaborated with the Northern Laboratory in obtaining what appears to be practical procedures to meet commercial requirements.

Two machines have been found that will loosen the pith without cutting the fiber. The first of these is the Hydrapulper which is best suited for the separation process starting with baled, dry bagasse. The second is the single-disc attrition mill, best suited for treating wet bagasse directly from the cane mill. Methods based on both machines have been operated on large pilot-plant scales and cost estimates have been made.

⁴ Processes mentioned are protected by patents or patent applications. See also P. M. Horton and A. G. Keller, U.S. Patent 2,650,176 August 5, 1953.

From the standpoint of low costs and utilization of pith, separation is best carried out at the sugar mill. In doing so it is possible to recover about two-thirds of the sugar left in the bagasse. The bagasse is upgraded into clean fiber and pith, so that these products may be used to their best advantages. The process uses no new machinery and since every step of the operation is well known no serious problems should exist in installing it. (Flowsheet, Figure I).

In its first step the process consists in treating bagasse from the cane mill, on a conveyor at 50-percent moisture content, with about an equal weight of water. The mass is then passed through a single-disc attrition mill, of the type used for grinding feed, using a special plate and a wide opening between the fixed and rotating plates. Such a 36-inch mill has a capacity of 100 short tons bagasse, O.D. per 24 hours, and a power consumption of 1 hp. per daily ton. Water does not drain from the material as it comes from the attrition mill. It is conveyed through a sugar press of 3 rolls, such as is used in the cane mill, whereupon the added water is now extracted. Its volume represents about two-thirds of the water used in maceration; it contains two-thirds of the sugar left in the bagasse; and it is returned to the cane mill as a part of the maceration water. Depending on the disposition to be made of pith or of fiber, the mass may be either dried and screened, or may be screened moist and then either the pith or fiber dried as desired.

The method which consists first of drying the mass and then screening it is to be preferred, if the pith is to be obtained in dry form. In this case the material from the sugar press is conveyed to a rotary drier and dried to about 15 to 20-percent moisture content. Since most of the sugar has been extracted from the material, it will dry with less caramelization and loss than is now being obtained in sugar houses drying bagasse. Since the pith has now been loosened from the fiber it is possible to make a good separation of pith and fiber by screening. For this purpose a set of 3 vibrating screens supplied with plates having round holes of selected diameter is used. The pith fraction passes all 3 screens, while materials collected on the screens are combined to make up the fiber fraction. The fiber may now be baled, and sold for papermaking, litter, mulch, or other purposes. This dry fiber, if kept protected from rains, will not undergo fermentation, or rotting; so that a saving of at least 10 percent fiber is assured as compared with purchasing wet bagasse. Furthermore, stronger pulps can be made from this dried fresh fiber (11).

The pith is clean and of excellent absorptive capacity. It is available to mix with blackstrap molasses as each is coordinately produced at the sugar house, and the mixture may be pelleted or otherwise packaged for use as feed.

If it is desired to obtain only dry fiber and to burn the pith, material from the sugar press may be screened directly over the same screens as used for the dried material. Screen capacities will be somewhat lower. Pith with a moisture content of 50 percent may be used as powdered fuel, along with oil or gas, or other fuel. The fiber is dried in a rotary

drier and baled. It is also possible to bale screened fiber in the wet state and burn the pith. Whether such wet-baled, separated fiber will store according to present methods without large losses due to rotting would have to be determined. It is possible that not enough sugar would be left in the fiber to induce the fermentation processes.

Estimates of the cost of obtaining dried, baled fiber and dried, pelleted pith by this method are given in Table 8. It will be noted that a fuel value of \$2.50 per short ton of bagasse O.D. and a cost of \$2.50 per ton for baling the fiber or for pelleting the pith is assumed. The costs of \$12.45 per ton for fiber baled and stored and \$8.29 for pelleted pith represents mill cost and does not include profit, or administrative and sales expense. For this method to be practical both fiber and pith would have to be marketed.

Table 9 gives cost estimates for method 2A. In this operation, wet bagasse from the sugar press is screened, the wet pith is sent to the boilers for fuel, and the fiber is dried in a rotary drier, baled and stored. It will be noted that in all these cost estimates the figure used by Keller for baling, piling, covering, and loading of \$6.50 less \$2.50 for baling costs is used to estimate storage and piling costs. The cost of \$12.40 for pith-free fiber by method case 2A is slightly higher than when both fiber and pith are baled and pelleted. However, in case 2A pith does not have to be marketed.

When it is necessary to prepare pith-free fiber from stored bagasse another method is required. Obviously passage of the dry bagasse through the attrition mill would result in severely cut fiber. This treatment would probably be worse than hammer milling. In selecting a wet process of separation it must be recognized that dry stored bagasse is difficult to wet. The best method for wetting bagasse is treatment in the Hydrapulper. This method is used commercially on a large scale. Whole bales are added to the Hydrapulper continuously and the wetted fiber, which is maintained at low consistency, is drawn off continuously through the extraction plate of the pulper.

We have found that when bagasse at high consistency is treated batchwise in the Hydrapulper the internal friction produced in the circulating mass loosens the pith during a period of 15-25 minutes. About 5 minutes of this time is required for wetting the material. The pulper is supplied with an extraction plate having holes $3/8$ inch in diameter. At the end of the treating period the draw-off valve is opened and water is added for about 2 minutes to the Hydrapulper at the same rate it is being drawn off. This washes out the pith leaving clean fiber ready for pulping. The pith contains coarse fibers which may be removed by passage over a Johnson screen having 0.075-inch holes. The fiber is used for pulping and the pith may be collected over a decker, and dewatered to 40 percent dry in a screw press. It can be dried in a rotary or flash drier. The pith and fine fiber after pressing may be used as powdered fuel. The flowsheet of this operation is given in Figure I.

Estimates of costs of separation by the Hydrapulper method are given in Table 10. In this case also the pith is burned. The whole, stored bagasse is charged into process at \$9.00/O.D. ton plus a 10-percent storage loss or at a total of \$9.90/O.D. ton. The costs of separation are higher by this process than by other methods of separation as will be noted from cost comparisons given in Table 11. In making the various estimates, costs of buildings have not been included. Differences in the fixed charges shown in Tables Nos. 8, 9, and 10 are due, respectively, to differences in capital costs and overhead. Costs of present methods of commercial screening of bagasse are not now available. It is believed, on the same cost basis for labor, overhead, etc., that screened, baled, stored bagasse will cost about the same as dried, baled, stored fiber (case 1 or 2A).

It has been pointed out that higher yields of much stronger and freer pulps can be obtained from pith-free fiber than from unscreened stored material. In Table 12 an estimate is given of the cost of pith-free fiber and whole bagasse required to produce a ton of pulp of three different kinds, based on average pulp yields. These figures do not take into account the larger amount of chemical required for pulping the whole bagasse and, in addition, the greater amount of power, labor, etc., required because of slower washing, screening, and slower paper-machine operation. These data show that costs of fiber (case 2A) and whole bagasse required to produce a ton of these pulps are practically the same, except for corrugating pulp. A recent large pilot-plant run to produce corrugating pulp from whole bagasse showed that it was so slow draining that it would not run on the paper machine, and only after passing the pulp over deckers to remove about 8.5 percent material, consisting of fines, could a satisfactory corrugating medium be made from it. On the other hand, a corrugating medium was easily made from the depithed fiber that was superior to commercial medium. These data suggest that with present methods of separation pith-free fiber can compete cost-wise with whole bagasse. From the pith-free fiber a high quality product will be obtained, instead of a low or fair grade product from whole bagasse.

A more recent process for depithing bagasse, either moist as it comes from the sugarcane mill or dry from bales, has been perfected by the Mexican Company now using the mechano-chemical process for pulping. The machine used in this process is of high capacity, relatively inexpensive to build, uses very little power, and requires little maintenance. Costs of depithing by this process will be lower than any of the above estimates.

The magnitude of the costs will change depending on fuel prices and the relative proportion of pith to fiber in the particular bagasse. As more pith is removed by mechanical treatment the costs of chemicals will be reduced, and the quality of the pulp will improve. The optimum for both quality and for low chemical costs per ton of pulp will only be obtained by using pith-free fiber.

Uses for Pith.

Cost analyses show that pith-free can be prepared best at the sugar mill during the grinding season. If an excess of bagasse for fuel exists, pith can replace some of the fiber used for fuel, with lowering of cost of \$2.50 per ton of fiber. If a better market than fuel can be found for pith then the sugar mill is in a position to benefit still further.

It has already been indicated that such a market exists in using pith as an absorbent for molasses to prepare cattle feed (12). The Northern Regional Laboratory has continued to investigate this subject, with the result that a method for determining the absorption capacity of pith or other feed ingredients has been reported (13). A comparison of the relative absorption capacity of wet-separated pith, dry-separated pith and other ingredients is given in Table 13. It will be noted that the absorption capacity of commercially separated pith is two-thirds to one-half that of wet-separated pith, while the capacity of common feed ingredients is from one-third to one-half of the same value. A mixture of 30 percent wet-separated pith and 70 percent 80°-Brix molasses will not cake in a humid climate on standing, while a mixture of this same proportion of molasses with commercially screened pith will cake. Both mixtures can be pelleted.

Blackstrap molasses and bagasse are the major byproducts of cane sugar manufacture (Table 5), and each is produced in almost the same amount when cane is ground for sugar extraction. While bagasse always has had a use as fuel, there have been times when blackstrap molasses in some areas had no use. The price of molasses always has been pegged to that of alcohol, and has fluctuated from ruin to riches. The latest U. S. Department of Agriculture report on the molasses situation (14) states that molasses prices stood at a record high (New Orleans-wholesale) 34.5 cents per gallon January 1951; they declined to 9.0 cents in the same market November 1952, and in October 1953 stood at 11.0 cents. The abrupt decline in prices in November 1952 was due to a reduction of the Cuban asking price to 4.5 cents (6.5 cents delivered) for molasses entering into alcohol production. With the increased manufacture of synthetic alcohol and the closing down in the fall of 1953 of the synthetic rubber plants using alcohol, the future for molasses in this market is not bright. From the standpoint of the sugar industry it is extremely important to divorce the molasses market and molasses prices from effects of conditions in the alcohol market. The report cited suggests that conditions for this are the brightest in history.

It has been repeatedly emphasized that the highest price market for molasses is in feeds. Use of molasses in feeding in the United States has steadily increased since 1945. The composition of dry solids of Louisiana blackstrap molasses is given in Table 14. At the present time a large number of authorities on animal feeding are investigating the use of roughages, molasses, urea or ammonium salts and necessary feed supplements for the

fattening, finishing, and feeding of cattle. For example, very large tonnages of ground corncobs are being fed in such rations. Much study is being devoted to the digestive action of rumen bacteria in making it possible for the animal to gain energy from the carbohydrates, cellulose and pentosans, of low-grade roughages. Molasses is evidently an important ingredient in promoting this action. New information suggests that it is desirable to absorb the molasses on a finely divided carrier so that it will not pass too quickly from the rumen. This prevents scouring which often takes place when liquid molasses is fed, and also seems to assist in producing more energy from the roughage. One-third of the protein requirement of the animal may be supplied in such feed by urea, or ammonium salts. Molasses may be ammoniated and urea can be dissolved in the molasses. Other feed ingredients such as minerals, vitamins and antibiotics, are available in the chemical markets, but the remainder of the protein requirement must be supplied from vegetable sources, generally oilseed meals.

Market surveys have indicated that there is a tremendous potential for molasses as feed in the United States, estimated at nearly a billion gallons per year. Merchandizing of liquid molasses to the small feeder, or farmer, particularly in the Northern States is difficult. Molasses in some dry form is desired.

Numerous efforts have been made in the Tropics to feed molasses mixed with screened bagasse. Two main conditions were probably responsible for failures. First, the type of cattle that could withstand the tropical climate were not desirable for meat. It would appear that the new breeds of cattle produced in Texas and Florida could be used in the Tropics satisfactorily. Secondly, while there is an excess of carbohydrates in most tropical countries, protein that can be used for feed is not plentiful. Since now at least one-third of the protein requirement can be supplied with urea or ammonia, protein requirements for feeding in the Tropics are less severe. Instead of shipping copra to America or Europe for extraction of oil, for example, its extraction in the Tropics would provide a source of protein.

Cattle, finished by lot feeding, or carried through the winter on rations such as those in Table 15 produce better meat than grass fed cattle. There seems to be a general belief that a protein diet based on meat is preferable to one based on vegetable proteins.

In some countries, where alcohol production is under government monopoly, and sugar production cannot be expanded because of lack of markets another approach to the production of pith-free fiber is possible. Sugarcane might be grown and ground as at present, but juice instead of being converted to sugar would be fermented directly to alcohol. This operation would require much less fuel. In this case the pith used as fuel could release even more fiber. Slops from the alcohol plant could be fermented to methane gas, which can be used efficiently in diesel engines to produce power directly. If such integrated operations proved to be sound economically, fiber for the paper industry could be provided at extremely low cost.

In considering the close integration of a sugar and pulp and paper mill a word of warning is necessary. The paper mill, if it is to make bleached paper must not burn bagasse or pith for fuel, because of the almost certain contamination of the bleached pulp with carbon particles. If the paper mill is to be located near a sugar mill, it must be so located as to avoid the same hazard.

Industrial Integration Raises Living Standards.

The wider availability of paper made possible through use of bagasse will of itself have far-reaching effects in improving social and economic conditions in less developed countries. The integration of the sugar and paper industries may have even a more profound effect, if advantage is taken of all the potential opportunities that such a relationship offers.

From the analysis presented the sugar mill is the logical place to prepare depithed fiber, in which even high-grade pith becomes available. By combining pith and blackstrap molasses and using this material for feeding cattle on the plantation the highest value will be realized for both. Silage and fodder is also available on the plantations in the form of tops. Chemicals, ammonia, or urea would be required as part of the feed; caustic and chlorine are needed for paper manufacture.

Protein also required for feeding might be provided as oilseed meal from a plant extracting vegetable oil, from seed locally produced. Caustic soda is also needed in oil refining. Using a refrigeration system based on ammonia gas, cattle could be slaughtered, packed, and sold locally and for export. Ammonia gas is finding increasingly greater use as a fertilizer. Thus based on integration between the paper and sugar industries, pith-free fiber could be made available for high-grade papermaking, pith and molasses for feed. This would solve the byproduct problem of the sugar industry, and at the same time act as a stimulus for the establishment of chemical, oil and packing industries. Such integration would provide all-year employment, get away from a one-crop system, and would undoubtedly raise living standards. Such a course needs enterprise, but the course is even now clearly enough marked.

LITERATURE CITED

- (1) Dymond, C. C.
1947. The Waste Products of the Sugar Cane Industry. Soil and Health 2, 168-173, 1947, Intl. Sugar J. XLIX (587), 286-287, November 1947.
- (2) Daubert, W. S.
1949. Cost of Trash to the Sugar Factory. Sugar 44 (7), 32-33, July 1949.
- (3) Singh, Kartar.
1945. Sugar 40 (10), 29-30, October 1945.
- (4) Vazquez, E. A.
1949. Some Products of Sugarcane Fiber. Ingeniera Azucarera, 26-27, September-October 1949.
- (5) Keller, A. G.
1952. Louisiana Sugar Cane Bagasse. Paper Trade Journal, 29-32, May 2, 1952.
- (6) Martin, L. F.
1950. Potential By-Products of Raw Cane Sugar Manufacture. The Sugar Journal 12 (11), 12, 13, 23, April 1950, and Grayson, "Recapitulation of Final Reports of Louisiana Sugar Cane Factories, Crops 1939-48," Sugar Bulletin 27 (22), 335, August 15, 1949.
- (7) Gastrock, E. A. and Lynch, D. F. J.
1939. Cost Evaluation of Bagasse for Industrial Utilization. Facts about Sugar 34 (6), 37-39, June 1939.
- (8) Spoelstra, H. J.
1933. Arch. Suikerind. 41 (III), 1-28, 1933.
- (9) Lathrop, E. C. and Munroe, T. B.
1934. Industrial Preservation of Crop Fibers. Ind. Eng. Chem. 26 (6), 594-598, June 1934. H. R. Hay and E. C. Lathrop. Storage of Crop Fibers and Preservation of Their Products. Paper Trade Journal 112 (9), 29-34, February 27, 1941.
- (10) Tatsuno, T., Nishio, F., Aoki, S., and Yamafuji, K.
1941. Concerning the Pentosans of Sugarcane. Bull. Agr. Chem. Soc. Japan 17 (9), 83, September 1941.

- (11) Wells, S. D. and Atchison, J. E.
1941. Production of Pulp from the Fibrous Elements of Sugar Cane Bagasse. Paper Trade Journal 112 (13), 34-38, March 27, 1941.
- (12) Lathrop, E. C., Aronovsky, S. I., and Naffziger, T. R.
1951. Increased Profits from Cane Sugar Byproducts. Sugar Journal 14 (1), 10, 12, 14, 25-32, June 1951.
- (13) Naffziger, T. R. and Mahon, H. I.
1953. Feed Evaluation--Determination of Absorption Capacity and Fibrous Material of Pith and Certain Feed Constituents. J. Agr. Food Chem. 1 (13), 847-851, September 16, 1953.
- (14) Sugar Reports No. 21-M, Molasses Issue, U. S. Department Agriculture
1953. Commodity Stabilization Service, Sugar Branch, November 1953.

Proximate analysis of various types of bagasse
(All values except moisture on oven-dry basis)

NRRL no.	Material	Extractives in										C and B					Cross and Bevan cellulose				
		Mois- ture	Ash	Lig- nin	Pento- sans	Hot :hol	Alco- :NaOH	water:ben- :zene	%	%	%	%	%	%	%	%	%	%	%	%	%
1267	Louisiana whole bagasse - stored (Lockport - 1941)	4.1	2.9	21.3	29.4	4.0	1.7	32.9	58.4	29.3	67.2	6.1									36.8
1267	Louisiana bagasse fiber - stored (Lockport - 1941)	6.8	2.0	20.7	30.0	2.4	1.6	28.4	61.4	31.7	70.0	10.0									38.7
1267	Louisiana bagasse pith - stored (Lockport - 1941)	12.2	4.6	21.3	29.9	3.1	1.7	36.1	54.6	30.3	62.8	5.7									32.3
1740	Louisiana whole bagasse - fresh (Houma - 1941)	4.9	2.4	18.9	30.0	8.8	6.0	35.9	53.3	27.9	67.3	7.0									33.4
1740	Louisiana bagasse fiber - fresh (Houma - 1941)	9.7	2.2	19.9	32.5	3.4	2.0	30.5	59.0	29.6	67.7	8.1									36.7
1740	Louisiana bagasse pith - fresh (Houma - 1941)	8.7	6.3	18.0	30.7	3.4	2.9	36.2	52.5	28.7	62.4	6.6									30.6
7892	Florida whole bagasse - fresh- dry screened (Clewiston - 1948)	7.3	2.2	18.1	27.9	11.2	10.8	39.9	52.0	26.9	68.0	4.7									33.7
7892	Florida bagasse fiber - fresh (Clewiston - 1948)	7.2	2.0	19.1	30.9	4.5	2.6	31.2	60.4	29.0	67.2	4.5									38.8

Table 1--Continued

Proximate analysis of various types of bagasse
(All values except moisture on oven-dry basis)

NRRD no.	Material	Mois- ture	Ash	Lig- nin	Pento- sane	Extractives in				C and B				Cross and Bevan cellulose			
						Hot water	:hol :ben- :zene	:Alco- :NaOH	1% NaOH	Ash free	Pento- sane	Ash free	Pento- sane	Alpha- cellulose	Alpha- ash	Pento- sane	Alpha-bas original
7892	Florida bagasse pith - fresh (Clewiston - 1948)	8.9	3.4	18.2	31.4	4.6	2.5	35.0	53.9	26.2	63.4	4.0	32.8				
9940	Florida whole bagasse - variety Cl. 41-223 (Clewiston - 1952)	8.6	1.0	18.2	26.6	15.1	7.0	40.7	48.0	28.1	66.9	4.7	30.6				
9941	Florida whole bagasse - variety F. 31-436 (Clewiston - 1952)	10.1	1.6	16.4	27.4	15.5	6.4	43.2	48.8	32.7	66.5	5.3	30.8				
9942	Florida whole bagasse - variety F. 31-962 (Clewiston - 1952)	10.5	2.2	18.6	28.7	9.8	8.0	40.0	49.0	26.5	67.7	5.2	31.5				
9992	Hawaiian whole bagasse - variety 8560 (1952)	13.2	5.4	21.3	27.7	5.7	3.2	33.9	50.2	27.4	69.6	8.8	31.8				
9992	Hawaiian bagasse fiber - variety 8560 (1952)	5.6	2.0	21.1	30.7	2.4	3.6	28.8	56.0	28.8	73.4	10.4	38.3				
9992	Hawaiian bagasse pith - variety 8560 (1952)	7.1	3.3	20.0	33.0	1.5	2.1	30.8	53.5	29.7	62.7	6.7	31.5				
9333	Hawaiian whole bagasse (Laupahoehoe Sugar Co.)	8.0	1.9	22.5	31.2	3.4	2.1	31.4	55.4	27.7	72.5	8.3	34.3				

Proximate analysis of various types of bagasse
(All values except moisture on oven-dry basis)

NBSL no.	Material	Mois- ture	Ash	Lig- nin	Pento- sans	Extractives in				C and B				Cross and Bevan cellulose			
						Alco- hol	Hot water	ben- zene	NaOH	Ash free	Pento- sans	cellulose	Alpha as run	Ash free	Pento- sans	Alpha as run	origina ash and pentosa free
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
9573	Hawaiian whole bagasse - variety 1933 (Ewa Plantation)	7.7	2.6	19.3	31.3	4.0	3.6	31.3	55.0	33.4	62.6	8.2	31.6				
9851	Hawaiian whole bagasse - variety 1933 (Oahu Sugar Co.)	7.9	3.3	20.1	31.0	2.7	3.4	32.0	52.0	32.4	65.7	7.4	31.7				
10081	Puerto Rican whole bagasse (Aguirre 1951, 1952)	7.5	3.9	18.1	29.6	8.0	5.4	27.3	50.9	31.1	63.7	7.0	30.1				
10081	Puerto Rican bagasse fiber (Aguirre 1951, 1952)	11.5	1.2	19.8	31.6	1.4	2.7	27.3	59.9	30.4	67.2	5.7	40.2				
10081	Puerto Rican bagasse pith (Aguirre 1951, 1952)	4.9	3.2	18.8	31.9	2.8	2.9	30.3	53.9	30.3	60.4	6.4	32.6				
10564	Mexican bagasse pith (San Cristobal, 1953)	6.2	4.9	22.4	29.9	7.6	2.3	40.1	46.0	25.5	61.3	5.5	26.6				
10566	Philippine whole bagasse (Negros Island, 1952)	10.2	2.3	22.3	31.8	2.8	3.0	31.3	56.8	30.6	70.2	12.5	34.9				
10566	Philippine bagasse fiber (Negros Island, 1952)	5.3	1.2	21.8	31.2	1.9	2.1	26.8	62.9	31.9	72.0	9.1	41.2				
10566	Philippine bagasse pith (Negros Island, 1952)	3.3	2.6	22.5	33.2	3.6	2.7	36.2	55.4	32.2	66.8	5.7	34.9				

g/pentosans = furfural x factor 0.8.

Analysis by Northern Utilization Research Branch.

Table 2

Variations in true fiber and pith content of certain varieties of Florida sugarcane. Percent based on dry bagasse free from dirt and solubles

Cane variety:	Fiber	Pith	Fiber ratio Pith
	1	1	
F. 31-436	69.6	30.4	2.289
P.O.J. 2725	65.4	34.6	1.890
Cl. 38-32	78.1	21.9	3.566

Private communication October 1953.

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Table 3

Approximate tonnage of waste constituents from annual sugar crop South Africa

Constituent:	1,000 tons	% at moisture content produced
Sugarcane	5,000	100.00
Trash	575	11.50
Tops	386	7.75
Bagasse	1,900	38.00
Filter cake	250	5.00
Molasses	162	3.324

Table 4

Humus and fertilizer constituents of cane tops
and trash in terms of dry substance

Constituent	Trash	Tops
	$\frac{1}{2}$	$\frac{1}{2}$
Humus	9.23	6.92
Nitrogen	0.27	0.90
Total ash	7.29	7.46
P ₂ O ₅	trace	2.70
K ₂ O	3.20	23.30

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Table 5

Average composition of materials obtained in processing a ton of
sugarcane in 1948 crop

Based on recapitulation of final reports

Cane	1 ton				
Fiber	229 lb.	Bagasse	648 lb.	(Fiber	229 lbs.
Sucrose	191 lb.	(Raw sugar	146.2	(Nonsucrose	11
Loss undeter- mined	5.4	(Press cake	91.3	(Sucrose	19.9
	185.6 lb.	(Molasses	84.0	Sucrose	140.3
		(		Sucrose	3.8
Nonsucrose	63 lb.	(		(Sucrose	21.7
				(Invert	20.0
				(Nonsugar	23.5
				(Acon. Acid	2.0
				Wax	0.8
			Press cake	Minor const.	0.5

Table 6

Proximate physical analysis of various samples of whole bagasse.
Results reported on original bagasse oven-dry basis

Type of whole bagasse	: Florida : variety : F. 31- : 962 : (1952)	: Florida : variety : Cl. 41- : 223 : (1952)	: Louisiana : Thibodaux : stored : (1952)	: Hawaiian : variety : 8560 : (1952)	: Puerto : Rico : Aguirre : (1951-52)	: Philippine : Islands : Negros : (1952)
	%	%	%	%	%	%
Fiber	58.0	60.7	64.4	60.5	60.1	68.6
Pith	22.8	24.3	25.2	32.9	25.5	23.8
Solubles, dirt, and loss	19.2	15.0	10.4	6.6	14.4	7.6

Table 7

Proximate composition of various fractions of bagasse obtained by passing through a series of sieves of decreasing mesh size. On basis of dry substance

Mesh of sieve in mm.	2	2-0.75	0.75-0.3	0.-0.15	0.15
Ash	1.31	3.11	4.97	5.56	12.38
Cold water extr.	0.06	0.13	0.37	0.50	1.52
Hot water extr.	1.36	1.82	2.68	4.48	4.80
Dilute NaOH extr.	29.52	31.67	35.24	37.89	40.19
Alcohol benzene extr.	1.74	2.36	2.57	2.89	3.27
Lignin	21.14	21.11	21.61	22.06	22.10
Pentosans	30.62	29.35	28.26	27.21	26.38
Cellulose	58.50	53.11	48.82	46.59	42.94
Alpha cellulose	41.25	37.17	33.85	31.94	29.10

Table 8

Estimated operating expense to separate whole bagasse into pith-free fiber and pith. Case 1 - whole bagasse dried before screening, fiber baled; pith mixed with molasses and pelleted. Yield 21.6% pith, 68.4% fiber, 10% dirt and loss

Fuel value bagasse \$2.50 O.D. ton

Estimate based on O.D. short ton

Fuel and power	\$1.080
Labor, supervision, maintenance, supplies	1.406
Fixed charges	<u>1.481</u>
Total	3.967
Credit for sugars recovered	<u>1.000</u>
	2.967
Cost/O.D. ton fiber or pith 90% yield	3.296
Fuel value/O.D. ton pith or fiber	2.500
Cost/O.D. ton baling fiber, or pelleting pith	<u>2.500</u>
Cost/O.D. ton baled fiber or pelleted pith	8.296
Cost stacking, covering piles, loading (Keller)	<u>4.000</u>
Cost stored pith-free fiber/O.D. ton	12.296
Cost pelleted pith/O.D. ton	8.296

Table 9

Estimated operating expense to separate whole bagasse into pith-free fiber and pith. Case 2A - fiber dried and baled after wet screening; pith burned wet as fuel. Fuel value \$ 2.50 O.D. ton. Yield 21.6% pith, 68.4% fiber, 10% dirt and loss

Estimate based on O.D. short ton

Fuel and power	\$0.631
Labor supervision, maintenance, supplies	1.336
Fixed charges	<u>1.342</u>
Total	3.309
Credit for sugars recovered/O.D. ton bagasse	<u>1.000</u>
Net operating expense/O.D. ton	2.309
Cost/O.D. ton fiber or pith 90% yield	2.565
Net cost separating pith/O.D. ton fiber	
Cost separation/O.D. ton ~~\$~~ .89	<u>0.890</u>
Total cost separation fiber/O.D. ton	3.455
Fuel value/O.D. ton fiber	2.500
Cost baling/O.D. ton fiber	2.500
Cost stacking, covering piles, loading (Keller)	<u>4.000</u>
	12.455

Table 10

Estimated cost per O.D. ton of separating baled bagasse into pith-free fiber and pith. Fiber to be pulped wet, pith to be burned wet.
 Cost baled bagasse \$9.00 stored plus 10% storage loss -
 Total \$9.90. Yield 21.6% pith, 68.4% fiber,
 10% dirt and loss

Estimate based on O.D. short ton

Raw material cost	\$9.90
Power and water	0.70
Labor, supervision, maintenance, supplies	1.45
Fixed charges	<u>1.57</u>
Total	13.62
Net operating cost/O.D. ton fiber and pith 90% yield	15.13
Net operating cost/O.D. ton fiber based on yield of 68.4% with pith of no value	19.91
Credit fuel value pith/O.D. ton fiber at \$2.50/ton	<u>0.79</u>
Net cost wet fiber for pulping/O.D. ton	\$19.12

Estimated cost per O.D. ton of preparing, storing, loading, and covering baled fiber and for pelleting pith or separating stored bagasse. Based on cost/O.D. ton

Model	RMSE	MAE	MAPE
ARIMA	0.0000	0.0000	0.0000
ARIMA + LSTM	0.0000	0.0000	0.0000
ARIMA + LSTM + GRU	0.0000	0.0000	0.0000
ARIMA + LSTM + GRU + BiLSTM	0.0000	0.0000	0.0000
ARIMA + LSTM + GRU + BiLSTM + Attention	0.0000	0.0000	0.0000

Comparison of costs of pulps in terms of raw fiber based on costs of
bagasse - pith-free fiber - Case 1 \$12.215/O.D. ton;
Hydrapulper, \$19.12/O.D. ton; and stored bagasse
(10% storage loss) \$9.00/O.D. ton

		Pith-free fiber				
			Cost/O.D.			
	Yield	ton pulp			Whole bagasse	
		Case 2A	Hydrapulper	Yield	Cost/ton	
					O.D. pulp	
Bleached						
80 brightness	48	25.43	39.83	37	26.73	
Unbleached	60	20.35	31.87	48	20.61	
Corrugating	75	16.25	25.49	65	15.25	

Table 13

Data on absorption capacity of bagasse pith and feed
absorbents used in livestock feeds

	Absorption		
	Apparent density, lb./cu. foot	Av. absorption, g.water/3-g. sample	Time f absorpt sec.
Wet-separated bagasse pith prepared by NRRL			
Scheme 1			
Hawaiian bagasse	2.6	26.0	40
Hawaiian bagasse specially screened	2.0	29.5	50
Puerto Rican bagasse	2.2	25.8	58
Florida bagasse	2.5	24.3	42
Scheme 2			
Hawaiian bagasse	3.0	24.5	42
Puerto Rican bagasse	3.3	26.2	50
Florida bagasse	3.5	23.1	39
Scheme 3			
Hawaiian bagasse	3.4	24.9	68
Puerto Rican bagasse	3.3	26.2	100
Florida bagasse	3.7	25.5	59
Dry-screened pith from various sugar companies			
Company A dehydrated fines	4.8	15.3	60
Company A screen dust	5.4	13.6	110
Company A dust from dust collector	4.2	14.6	111
Company B 40-mesh dust	4.5	13.7	--
Company B screened pith	5.7	20.3	--
Alfalfa meal, 17% dehydrated	18.5	7.7	400
Barley chaff	15.0	8.9	210
Barley dust	13.1	10.6	250
Beet pulp	14.6	14.4	270
Cottonseed meal	33.0	6.5	500
Gluten feed	25.7	6.8	27
Linseed meal, extracted	30.4	8.2	--
Malt sprouts	15.9	14.9	3200
Oat feed, No. 9 or B grade	18.7	7.9	25
Pin oats, hulls, and dust	8.0	11.7	160
Oats, pulverized	24.8	5.5	1860
Screenings, ground grain	19.1	6.7	63
Screenings, lightweight No. a	16.8	8.2	25
Screenings, lightweight No. b	17.5	7.7	45
Screenings, soybean	22.7	12.0	260
Soybean meal, extracted	40.3	6.0	40
Wheat bran	11.4	11.4	82
Wheat and elevator dust	10.0	13.6	75
Wheat hulls and dust	14.4	11.1	65

Table 14

Composition of dry solids of Louisiana blackstrap
from 23 factories in 1950^{1/}

	Minimum	Maximum	Average
	1	1	1
True sucrose	36.6	50.6	44.5
Reducing sugars ^{2/}	21.8	38.9	26.1
Total sugars	63.8	80.1	70.6
Carbonate ash	7.8	16.8	11.8
Organic nonsugars ^{3/}	12.1	21.6	17.6
Sulphated ash (Total)	11.4	21.7	15.1
Protein (N x 6.25)	1.36	2.88	2.17
Potash (K ₂ O) ^{4/}	3.1	9.5	6.4
Lime (CaO)	0.66	1.28	0.86
Magnesia (MgO)	0.32	0.91	0.61
Silica (SiO ₂)	0.36	1.06	0.67
Sulphate (SO ₃)	0.34	1.75	1.09
Chloride (Cl)	0.33	2.11	0.85
Aconitate (C ₆ H ₅ O ₆)	3.33	6.99	4.97
pH	5.54	6.13	5.84
Free acidity ^{5/}	0.62	1.72	1.07

- 1/ C. A. Fort, B. A. Smith, C. L. Black, and L. F. Martin, "Aconitic Acid Content and Composition of Louisiana Blackstrap Molasses," Sugar, October 1952.
- 2/ More correctly stated as reducing substances, as a portion amounting to 10-20 percent of the total reducing power is not derived from sugars.
- 3/ The sum of the total sugars and carbonate ash subtracted from total dry solids.
- 4/ The potash values are calculated and include minor bases such as iron, sodium, and aluminum.
- 5/ Titrated acidity determined by pH meter to pH 8.3 calculated as aconitic acid percent on dry solids. The choice of aconitic acid to put the acidity on a gravimetric basis is strictly arbitrary.

Table 15

Roughages containing molasses used as rations for cattle

	: Per steer :	: Per steer :
	: daily :	: daily :
	: lb. :	: lb. :
Ground corncobs	16.66	
Cottonseed hulls		23.06
Soybean oil meal	2.18	2.18
Molasses feed (45% molasses) ^{1/}	1.00	1.00
Fish solubles	.07	.07
Bone meal	.18	.18
Salt	.06	.06
Vitamin A and D concentrate	.01	.01

^{1/} Could be made of 50 percent pith and 50 percent blackstrap.
T. W. Perry and W. M. Beeson, "Corncobs, popcorn cobs,
cottonseed hulls as grass silage as roughages for growing
steers." A. H. - 80 (5M) Purdue University, Agricultural
Experiment Station, Lafayette, Indiana, April 25, 1952.

Figure 1

Flowsheet of attrition-mill method for separating wet bagasse at the sugar house into pith-free fiber and pith

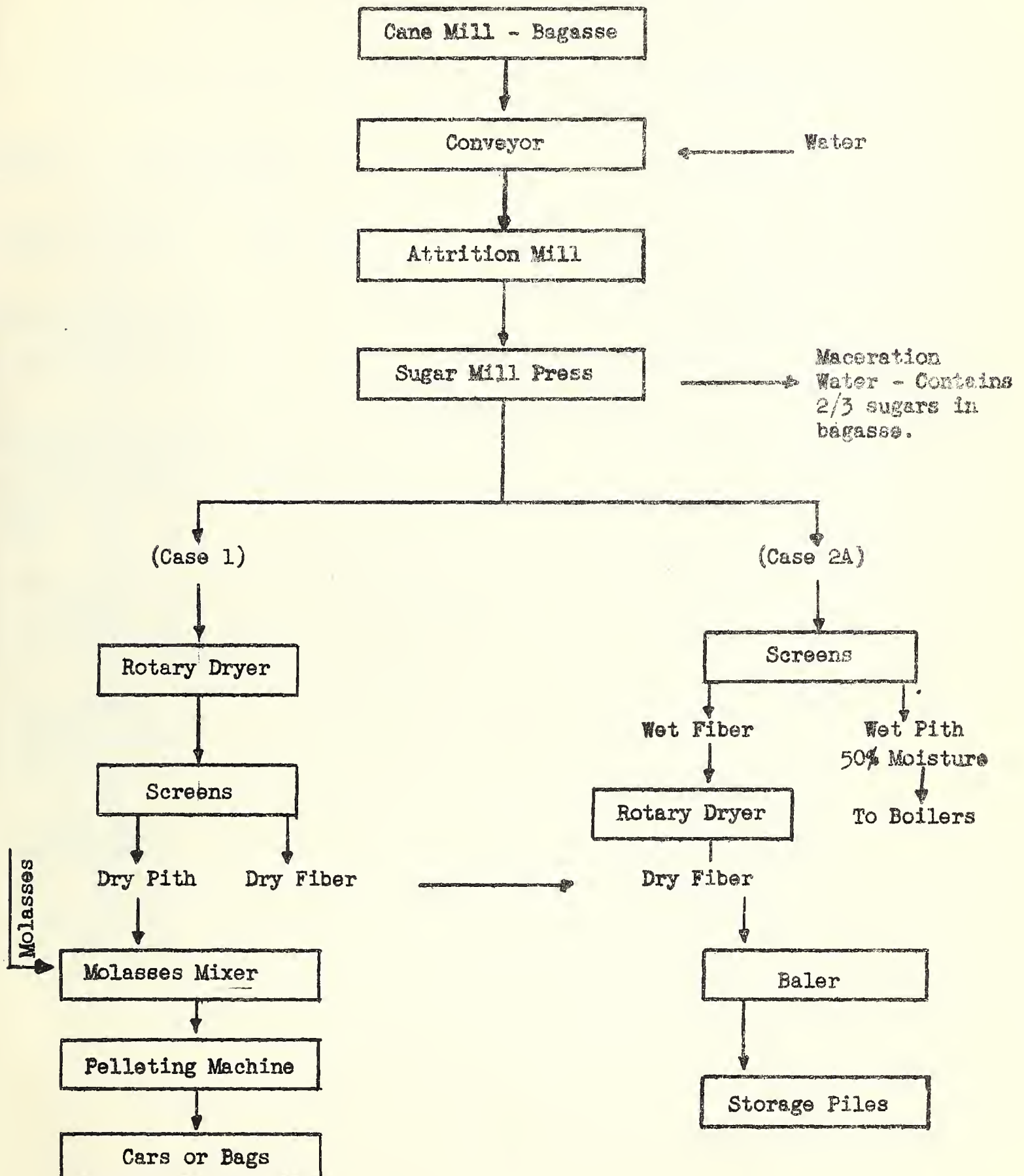
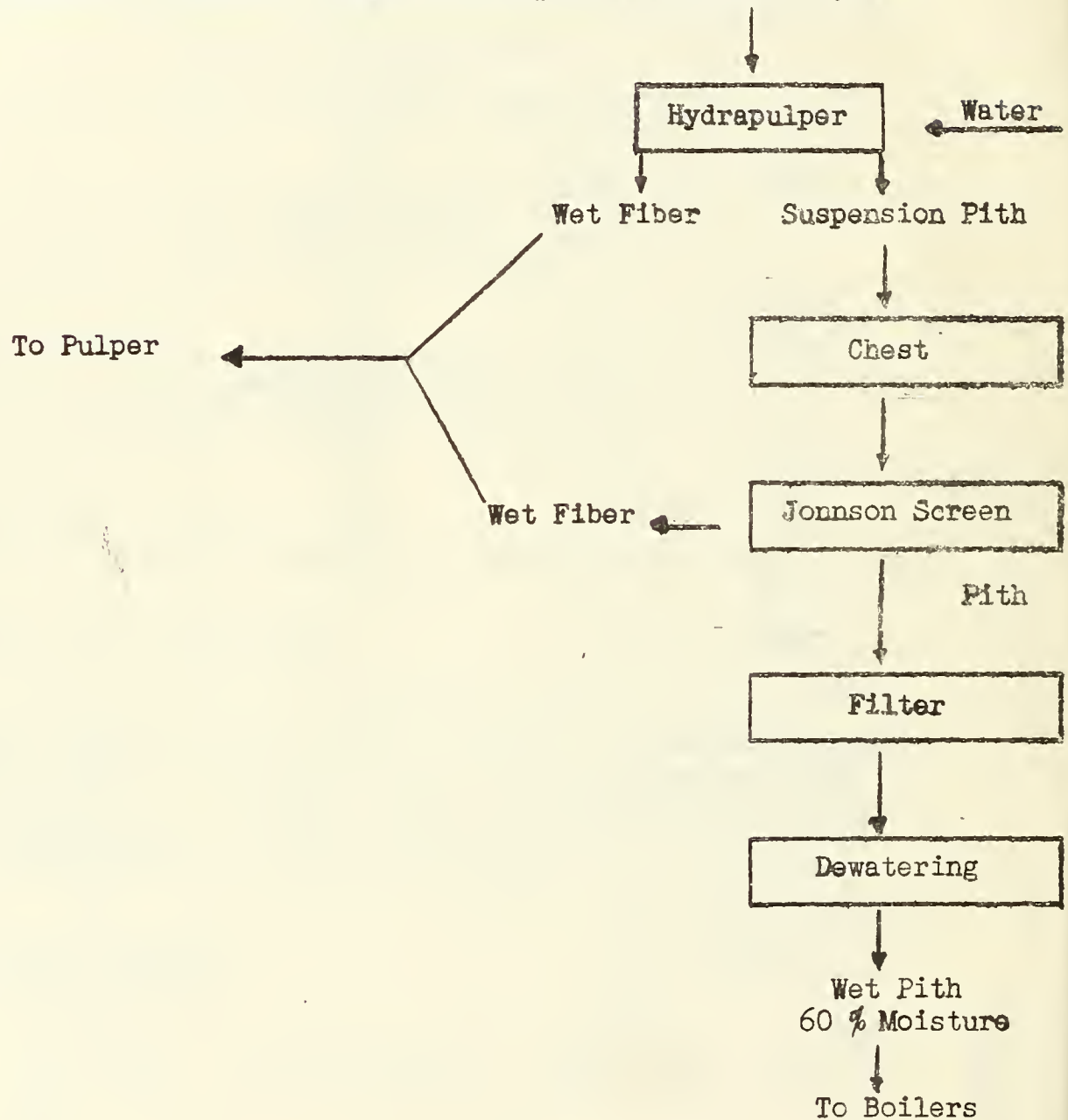


Figure II

Flowsheet of Hydrapulper method for separating stored bagasse at pulp mill into pith-free fiber and pith

From bale breaker - screen to remove loose pith - Screened Bagasse





1

2